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RESEARCH IN APPLIED MATHEMATICS RELATED TO NONLINEAR
SYSTEM THEORY(U) FLORIDA UNIV GAINESVILLE CENTER FOR
MATHEMATICAL SYSTEM THEORY R E KALMAN AUG 85

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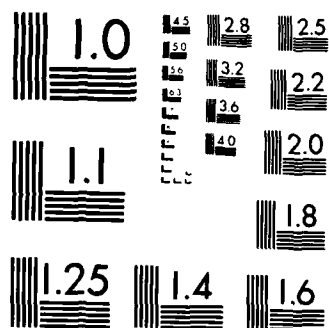
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RESEARCH IN APPLIED MATHEMATICS RELATED TO
NONLINEAR SYSTEM THEORY

Final Report

August 1985

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10 August 1981 through 9 August 1984

CENTER FOR MATHEMATICAL SYSTEM THEORY
UNIVERSITY OF FLORIDA
GAINESVILLE, FL 32611

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1. BRIEF SUMMARY OF ACTIVITIES UNDER GRANT

During many years in the past, funds from this grant were used primarily to support postdoctoral research at the Center for Mathematical System Theory at the University of Florida. During the period covered by this report, the following postdoctorals were involved:

J. HAMMER (1980 to 1982)

J. C. BIRGET (1983 to 1985)

Such support is limited to two years but is usually less.

In addition, several predoctoral students were also supported, albeit on a much lower financial level. This list includes A. OZGULER, P. KHARGONEKAR, J. RIBERA, and T. GEORGIU. Also supported was the Principal Investigator (partial summer support only) and various short-term visitors (research "consultants") who lectured on their recent work directly relevant to Center research.

A complete list is given in Section 3.

During the present three-year period of the grant, the number of publications was quite large, compared to earlier periods. This was not due to a large increase of personnel, but simply to the fact that publications are subject to a long lag. Moreover, in any serious research program, several years may be necessary before the problems become clearly defined, but then the results come relatively quickly.

A number of external publications (for example, by ROUCHALEAU, HAZEWINKEL, and KAMEN) have been strongly influenced by the Center. These are not included in the list in Section 2 which is limited to work that actually carried acknowledgement to the Army Grant to which this report pertain. Even a cursory look at the system-theoretic literature, however, will show that the influence of the Center research went far beyond the works listed in this report.

Since its establishment in 1972, research at the Center for Mathematical System Theory has generated over 100 published papers. At the same time, the Center has served as a focal point for a considerable part of the system-theoretic research in the U. S. and elsewhere, through an active visitor program and through recruitment of outstanding doctoral students. This is especially true for the development and application of advanced algebraic and algebraic-geometric techniques in the system-theoretic context.

The Center is an interdisciplinary, interdepartmental group, a basic function of which is to provide coordination and collaboration between advanced mathematics and engineering. This is critical for a research program of this type. Direct interaction between persons of different but overlapping backgrounds is important not only in optimizing the chances of success in research but also in assuring that the results will be disseminated to wider engineering circles and facilitating subsequent practical utilization.

The national and international recognition achieved by the Center reflects a vigorous and effective research organization. We expect to fully continue the strong research activities at the Center in the future.

2. PUBLICATIONS SPONSORED BY THE GRANT

G. BASILE and F. HAMANO

- [1982] "On the smoothness of the output trajectories for a linear dynamical system", IEEE Transactions on Automatic Control, AC-27: 196-198.

J. C. BIRGET

- [1984a] "Iteration of expansions - unambiguous semigroups", J. Pure and Applied Algebra, 34: 1-55.
- [1984b] "Arbitrary vs. regular semigroups", J. Pure and Applied Algebra, 34: 57-115.
- [1984c] "Structure of finite semigroups and generalizations", to appear in Proceedings of the Marquette Conference on Semigroups, September 1984, Springer-Verlag.

J. C. BIRGET and J. RHODES

- [1984a] "Almost finite expansions of arbitrary semigroups", J. Pure and Applied Algebra, 32: 239-287.
- [1984b] "Group theory vis global semigroup theory", submitted to the J. Pure and Applied Algebra.

E. EMRE

- [1982] "On necessary and sufficient conditions for regulation of linear systems over rings", SIAM Journal on Control and Optimization, 20: 155-160.

E. EMRE and P. P. KHARGONEKAR

- [1982] "Regulation of split linear systems over rings: coefficient assignment and observers", IEEE Transactions on Automatic Control, AC-27: 104-113.

E. EMRE, P. P. KHARGONEKAR, and A.B. OZGULER

- [1982] "Systems over rings: output regulation and tracking", Proceedings of the 21st IEEE Conference on Decision and Control, December 1982, pages 408-413.

E. EMRE, A. B. OZGULER and P. P. KHARGONEKAR

- [1982] "Output regulation and tracking for generalized linear systems", March 1982, unpublished.

T. T. GEORGIU

- [1983] "Partial realization of covariance sequences", Ph.D. dissertation, University of Florida.
- [1984] "Topological aspects of the Caratheodory problem", to appear in the Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, San Diego, March 1984, 4 pages.

T. T. GEORGIU and P. P. KHARGONEKAR

- [1982a] "On the partial realization problem for covariance sequences", Proceedings of the Princeton Conference on Information Sciences and Systems, March 1982, page 181.
- [1982b] "Partial realization of covariance sequences", September 1982, 31 pages, unpublished.

F. HAMANO and G. BASILE

- [1983] "Unknown input present state observability of discrete time linear systems", Journal of Optimization Theory and Applications, 40: 298-307.

J. HAMMER

- [1981a] "On causality, inverses and feedback", presented at the Second International Symposium on Dynamical Systems, University of Florida, February 1981, 4 pages.
- [1981b] "On internally stable linear control", Proceedings of the 1981 International Symposium on the Mathematical Theory of Networks and Systems, Santa Monica, May 1981, 5 pages.
- [1981c] "On stability, causality, and dynamic output feedback", July 1981, 51 pages, unpublished.
- [1982a] "On interchangeable or skew coprime matrices", January 1982, 22 pages, unpublished.
- [1982b] "On some properties of conditional moments in nonlinear filtering", SIAM Journal on Control and Optimization, 20: 497-505.
- [1983a] "Linear dynamic output feedback: invariants and stability", IEEE Transactions on Automatic Control, AC-28: 489-496.
- [1983b] "Feedback representation of precompensators", International Journal on Control, 37: 37-61.

- [1983c] "Pole assignment and minimal feedback design", International Journal on Control, 37: 63-88.
- [1983d] "Stability and nonsingular stable precompensation: an algebraic approach", Mathematical System Theory, 16: 265-296.

J. HAMMER and M. HEYMANN

- [1981] "Linear system factorization: feedback and stability", Proceedings of the Bielefeld-Rome Workshop on Linear and Nonlinear Systems, Bielefeld, W. Germany, June 1981, 3 pages.
- [1982] "Linear system factorization", in FEEDBACK CONTROL OF LINEAR AND NONLINEAR SYSTEMS, Lecture Notes in Control and Information Sciences, Vol. 39, D. Henrichsen and A. Isidori (editors), Springer-Verlag.
- [1983a] "Factorization of linear systems: a generalized framework", Linear Algebra and Its Applications, 50: 321-352.
- [1983b] "Strictly observable linear systems", SIAM Journal on Control and Optimization, 21: 1-16.

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- [1984] "Decoupling of linear systems by dynamic output feedback", Mathematical System Theory, 17: 135-157.

R. E. KALMAN

- [1982a] "Identifiability and problems of model selection in econometrics", in ADVANCES IN ECONOMETRICS, edited by W. Hildebrand, Cambridge University Press, pages 169-207.
- [1982b] "On the computation of the reachable/observable canonical form", SIAM J. Control and Optimization, 20: 258-260.
- [1982c] "Realization of covariance sequences", in TOEPLITZ CENTENNIAL, edited by I. Gohberg, Birkhauser, pages 135-164.
- [1982d] "System identification from noisy data", in DYNAMICAL SYSTEMS II, edited by A. R. Bednarek and L. Cesari, Academic Press, pages 331-342.
- [1982e] "Identifiability and modeling in econometrics", DEVELOPMENTS IN STATISTICS, edited by P. R. Krishnaiah, Academic Press, vol. 4, pages 97-136.

- [1982f] "Identification from real data", in CURRENT DEVELOPMENTS IN THE INTERFACE: ECONOMICS, ECONOMETRICS, MATHEMATICS, edited by M. Hazewinkel and A. H. G. Rinnooy Kan, D. Reidel, Dordrecht, pages 161-196.
- [1984] "We can do something about multicollinearity!", Communications in Statistics, 13: 115-125.

E. W. KAMEN and P. P. KHARGONEKAR

- [1982] "A transfer function approach to linear time-varying discrete-time systems", Proceedings of the 21st IEEE Conference on Decision and Control, December 1982, pages 152-157.
- [1984] "On the control of linear systems whose coefficients are functions of parameters", IEEE Transactions on Automatic Control, AC-29: 25-33.

E. W. KAMEN, P. P. KHARGONEKAR, and A. TANNENBAUM

- [1984a] "Pointwise stability and feedback control of linear systems with noncommensurate time delays", Acta Applicandae Mathematicae, 2: 159-184.
- [1984b] "A local theory of linear systems with noncommensurate time delays", in PROCEEDINGS 1983 INTERNATIONAL SYMPOSIUM ON THE MATHEMATICAL THEORY OF NETWORKS AND SYSTEMS, Lecture Notes in Control and Information Sciences, No. 58, P. A. Fuhrmann (editor), Berlin, pages 521-540.

P. P. KHARGONEKAR

- [1981] "Canonical forms for linear-quadratic optimal control problems", Ph.D. dissertation, University of Florida, 91 pages.
- [1982] "On matrix fraction representations for linear systems over commutative rings", SIAM Journal on Control and Optimization, 20: 172-197.

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- [1982] "Further results on polynomial characterizations of (F, G)-invariant subspaces", IEEE Transactions on Automatic Control, AC-27: 352-366.

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- [1981] "Skew-prime polynomial matrices and invariant subspaces", Proceedings of the 1981 International Symposium on the Mathematical Theory of Networks and Systems, Santa Monica, CA, 5 pages.
- [1983] "Skew-prime polynomial matrices: the polynomial model approach", Linear Algebra and Applications, 50: 403-435.

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- [1981] "System theoretic and algebraic aspects of the rings of stable and causal stable rational functions", 56 pages, to appear in Linear Algebra and Applications.
- [1982] "The rings of stable rational functions: algebraic properties", Proceedings of the 21st IEEE Conference on Decision and Control, December 1982, pages 402-407.
- [1984a] "Regulator problem with internal stability: a frequency domain solution", IEEE Transactions on Automatic Control, AC-29: 332-343.
- [1984b] "On the regulator problem with internal stability", in PROCEEDINGS 1983 INTERNATIONAL SYMPOSIUM ON THE MATHEMATICAL THEORY OF NETWORKS AND SYSTEMS, Lecture Notes in Control and Information Sciences, No. 58, P. A. Fuhrmann (editor), Berlin, pages 563-573.

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- [1982] "On the relation between stable matrix fraction factorizations and regulable realizations of linear systems over rings", IEEE Transactions on Automatic Control, AC-27: 627-638.

P. P. KHARGONEKAR and A. TANNENBAUM

- [1984] "Noneuclidean metrics and the robust stabilization of systems with parameter uncertainty", to appear in IEEE Transactions on Automatic Control.

A. B. OZGULER

- [1982] "Skew-primeness in the regulator problem with internal stability", Ph.D. dissertation, University of Florida, 63 pages.

J. RIBERA

- [1982] "Identification of linear relations from noisy data", Ph.D. dissertation, University of Florida, 99 pages.

A. TANNENBAUM

- [1982] "Polynomial rings over arbitrary fields in two or more variables are not pole assignable", 6 pages, to appear in Systems and Control Letters.
- [1983a] "A note about linear systems on curves", accepted for publication by the Bulletin of the Canadian Mathematical Society.
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A. TANNENBAUM and P. P. KHARGONEKAR

- [1984] "On weak pole placement of linear systems depending on parameters", in PROCEEDINGS 1983 INTERNATIONAL SYMPOSIUM ON THE MATHEMATICAL THEORY OF NETWORKS AND SYSTEMS, Lecture Notes in Control and Information Sciences, No. 58, P. A. Fuhrmann (editor), Berlin, pages 829-839.

Y. YAMAMOTO

- [1982a] "Realization theory of infinite dimensional linear systems - part I", Mathematical System Theory, 15: 55-77.
- [1982b] "Realization theory of infinite dimensional linear systems - part II", Mathematical System Theory, 15: 169-190.

3. PERSONNEL SUPPORTED UNDER THE GRANT

(a) Regular Personnel

- Professor R. E. Kalman, Principal Investigator (partial summer support only).
- Dr. J. C. Birget, postdoctoral fellow (1983-1985) (now on faculty of University of Nebraska)
- Dr. T. Georgiou, doctoral student (now on faculty of Florida Atlantic University)
- Dr. J. Hammer, postdoctoral fellow (now on faculty of Case Western Reserve University)
- Dr. P. P. Khargonekar, doctoral student (now on faculty of University of Minnesota)
- Dr. A. B. Ozguler, doctoral student (now on faculty of Marmara Scientific and Industrial Research Institute, Kocaeli, TURKEY)
- Dr. J. Ribera, doctoral student (now on faculty of I. E. S. E., Barcelona, SPAIN)
- Dr. A. Tannenbaum, Visiting Professor (partial summer support only, now on faculty of McGill University, Montreal, CANADA)

(b) Visitors (several lectures and/or extended visits)

- B. W. Dickinson, Princeton University, Princeton, NJ
- R. Donagi, Harvard University, Cambridge, MA
- D. Findley, US Department of Commerce, Washington, DC
- P. A. Fuhrmann, University of the Negev, Beer Sheba, ISRAEL
- R. P. Guidorzi, Bologna University, ITALY
- H. Kimura, Osaka University, JAPAN
- S. Y. Kung, University of Southern California, Los Angeles
- E. B. Lee, University of Minnesota, Minneapolis, MN
- N. A. Lehtomaki, Honeywell Systems and Research, Minneapolis, MN
- A. Libgober, University of Illinois, Chicago, IL
- G. Marro, University of Bologna, ITALY
- T. Matsuo, Nagoya University, JAPAN
- J. L. Rhodes, University of California, Berkeley, CA
- Y. Rouchaleau, Ecole Nationale Supérieure des Mines, Paris, FRANCE
- J. D. Sargan, London School of Economics, ENGLAND
- E. D. Sontag, Rutgers University, New Brunswick, NJ
- G. C. Verghese, MIT, Cambridge, MA
- Y. Yamamoto, Kyoto University, JAPAN
- G. Zames, McGill University, CANADA

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